30" Bubble Chamber Documentation Report

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Abstract

This note will show how the boil off rate was determined for the helium dewar, serial #2026, Fermilab serial #32981, which was manufactured by Cryogenic Energy Company of Denver, Colorado.

Cool Down Procedure

The helium dewar is first subcooled using liquid nitrogen. After the helium dewar came to thermal equilibrium the remaining liquid nitrogen was blown out using gaseous nitrogen. Then the dewar was purged using helium gas. Following the helium purge the dewar was filled with liquid helium.

Data Taking Set Up

The boil off gas which exited the dewar was measured using a wet test meter model #14AH3 manufactured by GCA/Precision Scientific of Chicago, IL., Fermi serial #24944.

Before alowing the gas to enter the wet test meter it was boiled thru water.

Wet Test Meter Correction Factors

All the thermophysical properties of helium-4 were obtained from a U.S. Department of Commerce publication titled "Thermophysical Properties of Helium-4 From 2 to 1500 K with Pressures to 1000 Atmospheres" by Robert D. McCarty. The goal of a boil off rate test is to determine the heat leak performance of the test item at $70^{\circ}F$ and 760 mm Hg barometric pressure.

Since it is difficult to achieve the above conditions in a laboratory the following correction factors will have to be applied to the test data.

1) Barometer Pressure

Gas meters are volume indicators at 300 (^{o}K)

P (Atm)	Density (^{G}/cc)	Normalized Density
0.9	1.463×10^{-4}	0.9
1.0	1.625×10^{-4}	1.0
1.2	1.950×10^{-4}	1.2

To correct for barometric pressure changes the measured volume is multiplied by the normalized density factor which is the density at the testing pressure divided by the density at one atmosphere.

2) Barometric Pressure Change

Since the liquid saturation temperature changes with pressure it would not be appropriate to include the boil off which occured due to a drop in barometric pressure. (Liquid wants to cool down). It would however be appropriate to add the boil off which would have occured if there was not a rise in barometric pressure (liquid wants to warm up).

The amount of energy that is liberated or absorbed equals

$$V \cdot \rho_{LHe} C_p \cdot \frac{\Delta T}{\Delta P} \cdot \Delta P$$

V = the average number (cc) of LHe in the vessel; ρ_{LHe} = density of saturated liquid helium at 1 (atm); C_p = constant specific heat = 9.78 (^{J}/^{o}K-G); ΔT = change in temperature; ΔP = change in pressure.

Calculating $\Delta T/\Delta P$

Pressure	Liquid Saturation Temperature
0.9 (atm)	4.114 (^{o}K)
1.0	4.224
1.2	4.424

$\Delta T/\Delta P = 1.0$ (^{o}K/atm)

Dividing the above quantity by the latent heat of vaporization will yield how many grams of LHe will be evaporated, or might have been evaporated depending if there was a net rise or drop in the barometric pressure during the testing period.

$$SCF/HR = \frac{\text{(Grams of Helium)}}{\rho_{GHE}} \Big/ \text{Length of Test (in hours)}$$

ρ_{GHe} = density of gaseous helium at 1 (atm) and 300 (^{o}K)

$$(SCF/HR) \text{ boil-off correction} = \frac{V \times \Delta P \times 12.7}{\text{total test period - hrs}}$$

This factor is to be applied to the boil-off data after it has been corrected for pressure, temperature and water vapor pressure. It is to be added to the boil-off if the barometer has a net increase over the test period and subtracted if there is a net decrease in barometric pressure.

3) Gas Meter Temperature Correction

The temperature of the gas exiting the gas meter might not be 21 (^{o}C), therefore the volume reading has to be corrected.

T (^{o}K)	ρ = Density ($^{G}/_{cc}$)	Normalized Density
275	1.773×10^{-4}	0.916
300	1.625×10^{-4}	1.00
350	1.393×10^{-4}	1.17

$\frac{\Delta \text{ normalized density}}{\Delta T} = 0.005$ ($^{1}/^{o}$K) gas meter temperature correction factor

If the gas meter temperature is below 300 (^{o}K), take the volume reading multiply it by (0.0034)(ΔT) and add this amount to the volume reading if the gas meter temperature is above 300 (^{o}K) subtract the above amount from the volume reading. ΔT is the difference in temperature from 300 ^{o}K in this case.

4) Gas Meter Vapor Pressure

Precision wet test meter used for this boil-off measurement measures the total volume of saturated gas which passes through during the test period. To have an accurate reading the water vapor quantity must be subtracted from the total.

Volume corrector for V. P. =

$$\text{Measured vol} \times \frac{\text{Bar. Press} - \text{V. P.}}{\text{Bar. Pressure.}}$$

Water vapor pressure is available from steam tables. (Thermo-Dynamic Properties of Steam, Keenan and Keys, John Wiley and Sons, 1936). For convience, an excerpt from the steam table is

plotted in Fig. 1. This correction should be applied to each reading not averaged across several readings.

Reduction of Data Procedure

1. Apply the corrections listed in Sections 1, 3 and 4 to the data.
2. Then sum the corrected readings.
3. Divide the above readings by the number of hours that the test took.
4. Now apply the barometric pressure change correction Section 2.

A gas replacement factor must be calculated because some of the gas remains within the vessel to occupy the space which was formerly liquid. Simply stated this factor is the ratio of the densities of the vapor and the liquid added to one.

$$\text{Gas replacement factor} = 1 + \frac{1.689}{12.50} = 1.13512$$

To obtain the correct boil-off rate (ℓ/hr) per hour take the number obtained in step 4 and multiply it by the gas replacement factor.

	Gas Meter Time	Gas Reading	*Barometric Temperature	Pressure
	10:03	0.00 (liters)	24.0 ^{o}C	1.013 (atm)
2-14	1:03	600	24.0	1.011
	3:22	1080	24.0	1.011
	4:07 pm	1221	24.0	1.011
2-15	8:47 am	4020	24.0	1.014
	9:47	4191	24.0	1.014
	10:49	4367	24.0	1.014
	11.47	4540	24.1	1.014

12:47	4720	24.1	1.014
1:47	4930	24.1	1.013
2:47	5142	24.1	1.013

	Δt Change in Time	ΔV Change in Volume	(BCF) Barometric Pressure Correction Factor
10:03-1:03	3 hours	600 (liters)	1.013
1:03-3:22	2.32	480	1.011
3:22-4:07	0.75	141	1.011
4:07-8:47	16.67	2799	1.011
8:47-9:47	1.0	171	1.014
9:47-10:49	1.0	176	1.014
10:49-11:47	1.0	173	1.014
11:47-12:47	1.0	180	1.014
12:47-1:47	1.0	210	1.013
1:47-2:47	1.0	212	1.013

28.72 - length of test in hours

*The barometric pressure record for the testing in strip chart form is contained in Fig. 2.

ΔV x BCF	Temperature correction factor (TCF)	ΔV after correcting for temperature and pressure
607.8	0.01	601.7
485.3	0.01	480.4
142.6	0.01	141.2
2829.8	0.01	2801.5
173.4	0.01	171.7
178.5	0.01	176.7
175.4	0.01	173.7
182.5	0.01	180.7
212.7	0.01	210.6
214.8	0.01	212.7

Water vapor correction factor	ΔV after correcting for temperature, pressure and water vapor pressure
0.971	584
0.971	467
0.971	137
0.971	2720
0.971	167
0.971	172
0.971	169
0.971	175
0.971	204
0.971	+207
	5002 - corrected total volume of boil-off gas which was measured

$$\frac{\Delta V}{\Delta t} = \frac{5002}{28.72} = 174.2 \ (\ell/\text{hours})$$

Need to correct for the gas replacement factor.

$$(174.2)(1.13512) = 197.7 \ (\ell/\text{hours})$$

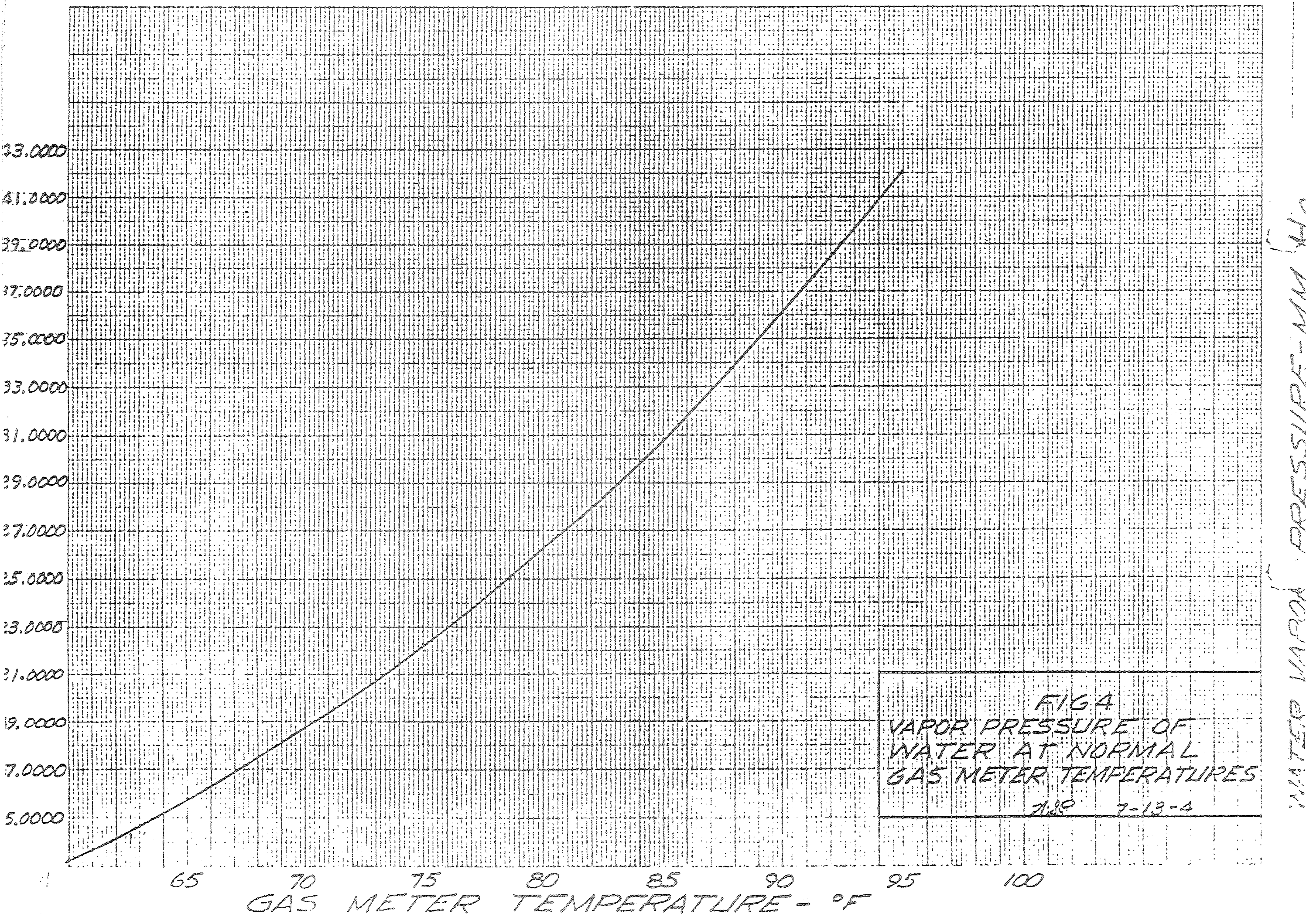
There is no need to apply the correction for a barometric pressure change during the test because the barometric pressure at the end of the testing period is the same as it was before the test was started.

Determining the Net Boil-off Rate Per Day

A 1000 (ℓ) dewar will efflux 313 (ℓ/hr) if it has a 1% net boil rate per day.

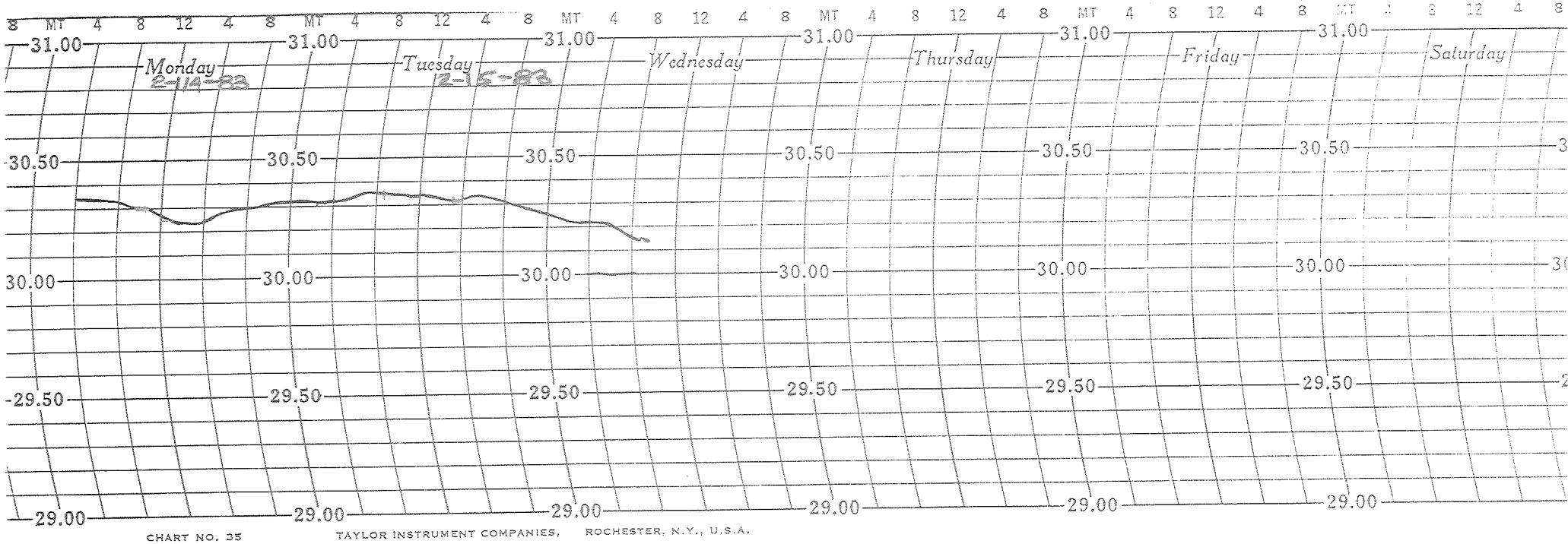
Therefore the net boil-off rate of this helium dewar is 0.65% per day.

FIGURE #1



65
70
75
80
85
90
95
100
GAS METER TEMPERATURE - °F
WATER VAPOR PRESSURE-MM Hg
FIG 4
VAPOR PRESSURE OF
WATER AT NORMAL
GAS METER TEMPERATURES
7-13-4

FIGURE #2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31.00
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Monday
2-14-63
Tuesday
2-15-63
Wednesday
Thursday
Friday
Saturday
CHART NO. 35
TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N.Y., U.S.A.